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DESCRIPTION

DIAPHRAGM PUMP AND COOLING SYSTEM WITH THE DIAPHRAGM PUMP

Technical Field

[0001]

The present invention relates to a diaphragm pump used for a cooling system or the like, and in particular, relates to a slim diaphragm pump capable of discharging liquid efficiently. Further, the present invention relates to a cooling system with the diaphragm pump used for cooling electronic equipment or the like.

Background Art

[0002]

As the performance of electronic equipment becomes higher and processing speed is enhanced, power consumption for electronic parts such as CPU increases. As a result, the heating value in the electronic parts becomes high, and it is absolutely necessary to have a technology that can efficiently dissipate heat generated from the electronic parts and that remains inside the electronic equipment in terms of ensuring reliable operation of the electronic equipment.

[0003]

As a cooling technique for a portable personal computer such as a notebook personal computer, instead of an air-cooled cooing system, there is proposed a water-cooled cooling system that can provide cooling by circulating liquid by a pump (for example, refer to Japanese Patent Laid-Open No. 2002-232174). The water-cooled cooling system is provided with

a closed-structure flow passage to be in thermally contact with heating parts, such as electronic parts, and a pump to circulate the liquid inside the flow passage. The cooling system dissipates heat by circulating the liquid that is heated by the heated parts with the pump, so as to provide cooling for the heated parts.

[0004]

As the pump for the cooling system, a piezoelectric pump, a kind of diaphragm pump, which is compact and capable of generating a high discharge pressure, is often used. The piezoelectric pump is usually provided with a pressure chamber with a suction port and a discharge port, a piezoelectric oscillator disposed on a wall of the pressure chamber, and a flow passage that is connected with the suction port and the discharge port. In the piezoelectric pump, the piezoelectric oscillator functions as a diaphragm in the diaphragm pump. The piezoelectric oscillator is provided with an elastic plate made of metal and the like and a piezoelectric element bonded to the elastic plate. When a voltage is applied to the piezoelectric element, the elastic plate (piezoelectric oscillator itself) is bent and displaced. In the piezoelectric pump, by oscillating the piezoelectric oscillator, pressure operating on the liquid is generated in the pressure chamber. Further, the suction port and the discharge port are provided with check valves to prevent backflow of the liquid so as to restrict the flow direction of the liquid from the suction port to the discharge port.

[0005]

Fig. 10 shows an example of a conventional piezoelectric pump. The piezoelectric pump shown in Fig. 10 is provided with piezoelectric oscillator 130 arranged to form an upper surface of pressure chamber 150. On the

lower surface of pressure chamber 150, suction port 121a is provided for ingesting the liquid and discharge port 121b is provided for discharging the liquid. Suction side flow passage 170a for supplying the liquid to suction port 121a is formed under pressure chamber 150, and is connected with suction port 121a. Discharge side flow passage 170b, a flow passage for the liquid discharged from discharge port 121b, is formed under the pressure chamber 150, and is connected with discharge port 121b. With this arrangement, the flow passage of the liquid in piezoelectric pump 100 is formed from suction side flow passage 170a to discharge side flow passage 170b through suction port 121a, pressure chamber 150, and discharge port 121b in order.

[0006]

Suction port 121a and discharge port 121b are respectively provided with suction valve 120a and discharge valve 120b. Suction valve 120a and discharge valve 120b are made from elastic members, such as silicon rubber, and respectively control the opening and closing of suction port 121a and discharge port 121b.

[0007]

Piezoelectric pump 100, arranged as described above, operates as follows. When piezoelectric oscillator 130 is displaced upward and the volume in pressure chamber 150 is increased, there is a negative pressure in pressure chamber 150. With this operation, suction valve 120a is opened and the liquid is supplied from suction side flow passage 170a into pressure chamber 150. At this time, by the action of discharge valve 120b, there is no backflow of the liquid from discharge side flow passage 170b to pressure chamber 150. Then, piezoelectric oscillator 130 is displaced in the opposite direction, and the volume of pressure chamber 150 is reduced. Then, since

the pressure in pressure chamber 150 is raised, discharge valve 120b is opened and the liquid is discharged toward discharge side flow passage 170b. At this time, since suction valve 120a operates, there is no backflow of the liquid from pressure chamber 150 to suction side flow passage 170a. Piezoelectric pump 100 functions as a pump by repeating the above-mentioned operations, and the liquid can flow in one direction.

[0008]

However, in conventional pumps, the flow passage from the suction side flow passage to the discharge side flow passage via the pressure chamber is formed in being bent. For example, in piezoelectric pump 100 shown in Fig. 10, suction side flow passage 170a and discharge side flow passage 170b are formed under pressure chamber 150, and are each connected with suction port 121a and discharge part 120b arranged on the lower surface of pressure chamber 150. Accordingly, when piezoelectric pump 100 operates and the liquid flows along the flow passage, the flow direction of the liquid is bent at a point where the liquid flows from suction side flow passage 170a into pressure chamber 150. The flow direction of the liquid which has passed through pressure chamber 150 is bent once again where the liquid flows from pressure chamber 150 to discharge side flow passage 170b. In this way, when the flow of the liquid is changed rapidly, the pressure of the liquid is largely lost. As a result, the amount of flow of the liquid passing through the flow passage is reduced, and therefore the pump efficiency is decreased. The decrease in pump efficiency indicates a decrease in the cooling efficiency of the cooling system.

[0009]

Further, in piezoelectric pump 100, suction port 121a, discharge port

121b, and respective flow passages 170a, 170b are positioned on/under the lower surface of pressure chamber 150. Accordingly, the thickness obtained by adding the thickness of pressure chamber 150 and the thickness of flow passages 170a, 170b means that the pump has a substantial thickness. The pump is incorporated in electronic equipment such as portable personal computers, and therefore it is desirable to make the pump thinner in order to reduce the thickness of electronic equipment.

Disclosure of Invention

[0010]

The present invention has its object to provide a diaphragm pump that enables an increase in pump efficiency by reducing the pressure loss of liquid and that enables reduction in thickness. Also, the present invention has its object to provide a cooling system that enables an increase in cooling efficiency by being provided with the diaphragm pump.

[0011]

To achieve the above-mentioned object, a diaphragm pump according to the present invention includes:

a pressure chamber formed into a flat shape and is filled up with liquid;

a suction side flow passage and a discharge side flow passage disposed at both ends of the pressure chamber so that axes thereof are aligned with each other and are connected with the pressure chamber;

check valves, respectively disposed on the suction side flow passage and the discharge side flow passage, at least one of the check valves being tilted relative to the direction of the axes; and

at least one diaphragm disposed on at least one of an upper surface

and a lower surface of the pressure chamber and for oscillation to make a volume of the pressure chamber variable.

[0012]

According to the present invention, the suction side flow passage and the discharge side flow passage are disposed at both ends of the pressure chamber so that the pressure chamber is sandwiched between the flow passages and the flow passages are connected with the pressure chamber. The suction side flow passage and the discharge side flow passage are extended in the same direction so that axes thereof are aligned with each other. Therefore, the flow passage for the pump, including the respective flow passages and the pressure chamber, is formed in a straight line without being bent, and thus the pressure loss of the liquid is reduced and the liquid flows efficiently. Also, check valves respectively disposed in the flow passages are tilted relative to the axial direction of these flow passages, namely, the flow direction of the liquid, and thus the pressure loss of the liquid is further reduced. Additionally, since the pressure chamber is formed into a flat shape and, since the suction side flow passage and the discharge side flow passage are disposed at both ends of the pressure chamber, the whole of the pump is reduced in thickness. The diaphragm is arranged on at least one upper surface and one the down surface of the pressure chamber so as to operate on a surface having a large area in the flat-shaped pressure chamber, and thus oscillation by the diaphragm is transmitted to the pressure chamber efficiently. Therefore, the driving source is reduced in size, work is saved, and the size of the pump is also reduced.

[0013]

Each of the flow passages may be formed so that the axes thereof are

positioned at the center of a cross-sectional shape of the pressure chamber on a surface orthogonal to the axes. Accordingly, the flow of the liquid in the pressure chamber is even around the axes. With this arrangement, since the axes of the respective flow passages approximately pass through the center of the pressure chamber, the space in the pressure chamber is approximately symmetric relative to the axes. Accordingly, the flow passage of the liquid is approximately symmetric relative to the axes, and thus the pressure loss of the liquid in the pressure chamber is reduced.

[0014]

Each cross-sectional shape of flow passages and the pressure chamber is formed in an approximate rectangle in cross section. In this case, these can be formed by a cutting process or the like, and thus manufacturing is easy. In particular, when the lower surfaces of the flow passages and the pressure chamber are formed on the same surface, manufacturing is easy. Further, since the flow passage is made flatly, the liquid is circulated efficiently. In order to further reduce the pressure loss of the liquid, the length of the pressure chamber, viewed from an upper surface in a direction orthogonal to the axes, may be continuously shortened toward the suction side flow passage or toward the discharge side flow passage. Also, a height of the pressure chamber may be continuously lowered toward the suction side flow passage or the discharge side flow passage. In both cases, the section of the pressure chamber is made smaller continuously toward the respective flow passages, and thus the pressure loss of the liquid in the pressure chamber is reduced.

[0015]

In the diaphragm pump according to the present invention, at least

one groove may be formed in a peripheral wall of the pressure chamber and can accelerate the flow of the liquid downstream in a flow direction. The groove may have a part with an opening opened to the pressure chamber, into which the liquid flows, and a side part with an opening opened to a peripheral wall surface of the pressure chamber, from which the liquid is discharged downstream in the flow direction. The groove may be extended in a radial direction while a point in the vicinity of the entrance of the discharge side flow passage is set as a center. By arranging the groove, when pressure is applied to the pressure chamber by the diaphragm, the liquid is discharged from the side part with an opening downstream and the flow of liquid is accelerated.

[0016]

The diaphragm pump may include: at least one intake opened to an upper surface of the suction side flow passage and is used to introduce bubbles mixed in the liquid; and a sealed space connected with the intake and is used to collect the introduced bubbles. The intake may be positioned in the suction side flow passage upstream relative to the check valve. Bubble collection means like this are arranged in this way, and thus the bubbles mixed in the liquid are collected and are prevented from entering the pressure chamber. In this way, by removing bubbles from the flow passages and the pressure chamber, the pressure loss of the liquid is further reduced. The intake is positioned in the suction side flow passage upstream relative to the check valve, and thus the bubbles are efficiently prevented from entering the pressure chamber.

[0017]

The diaphragm pump is a so-called piezoelectric pump in which the driving

source is a piezoelectric element. The piezoelectric element enables a reduction in the size and thickness of the pump.

[0018]

Further, the above-mentioned diaphragm pump is available for a cooling system that has a closed-structure flow passage for circulating liquid discharged from the discharge side flow passage in the diaphragm pump and for returning the liquid to the suction side flow passage. The cooling system cools electric equipment efficiently. In particular, the cooling system having a pump with the bubble collection means circulates the liquid efficiently for a long period because the bubbles in the flow passage are collected.

[0019]

Additionally, in this description, a "flat" pressure chamber is a pressure chamber in which a length of the pressure chamber in the height direction is shorter than one-half of the maximum length of the pressure chamber viewed from the upper surface in the axial direction, and than one-half of the maximum length in the direction orthogonal to the axis.

[0020]

According to the present invention, by adding ideas to the structure of the diaphragm pump, the pressure loss of the liquid is reduced and the pump is improved in pump efficiency and is reduced in thickness. Also, the cooling system is provided with the diaphragm pump, and thus the cooling system is improved in cooling efficiency and is reduced in thickness.

Brief Description of the Drawings

[0021]

[Fig. 1] Fig. 1 shows schematic views of a cooling system provided with a

piezoelectric pump of a first embodiment according to the present invention, Fig. 1(a) is a plan view showing a liquid passage in the cooling system, and Fig. 1(b) is a sectional view along line X-X in Fig. 1(a).

[Fig. 2] Fig. 2 shows the piezoelectric pump of the first embodiment, Fig. 2(a) is a lateral section view, and Fig. 2(b) is a longitudinal section view viewed from an upper surface side.

[Fig. 3] Fig. 3 shows the piezoelectric pump of a second embodiment, Fig. 3(a) is a lateral section view, and Fig. 3(b) is a longitudinal section view viewed from an upper surface side.

[Fig. 4] Fig. 4 is a perspective enlarged view showing one returning groove and a flow direction of liquid.

[Fig. 5] Fig. 5 is a partial enlarged view showing a modification of the shapes of returning grooves.

[Fig. 6] Fig. 6 is a section view showing a modification of the shape of a pressure chamber.

[Fig. 7] Fig. 7 shows one example of a piezoelectric pump according to a third embodiment.

[Fig. 8] Fig. 8 shows another example of a piezoelectric pump according to the third embodiment.

[Fig. 9] Fig. 9 shows further another example of a piezoelectric pump according to the third embodiment.

[Fig. 10] Fig. 10 is a section view showing a conventional piezoelectric pump.

Best Mode for Carrying Out the Invention

[0022]

Hereinafter, explanations are given of embodiments according to the present invention with reference to drawings.

[0023] (First Embodiment)

Fig. 1 shows schematic views of a cooling system provided with a piezoelectric pump of a first embodiment according to the present invention, Fig. 1(a) is a plan view showing a liquid passage in the cooling system, and Fig. 1(b) is a sectional view along line X-X in Fig. 1(a).

[0024]

Cooling system 10 shown in Fig. 1 is a water-cooled cooling apparatus preferably used for providing cooling for electronic equipment, such as a portable personal computer. Cooling system 10 is roughly provided with flow passage unit 60 in which circulation flow passage 60a is formed and piezoelectric pump 1 connected to flow passage unit 60 and is used to circulate liquid in the flow passage. Flow passage unit 60 and piezoelectric pump 1 provide a closed-structure flow passage. Inside the flow passage, liquid to be circulated is filled up.

[0025]

In flow passage unit 60, circulation flow passage 60a is formed in a predetermined pattern. There are no particular limitations to the sectional shape of circulation flow passage 60a, and may be rectangular or circular. In the case of flow passage unit 60 having a flat shape as in the first embodiment, circulation flow passage 60a is preferably formed in a rectangle in the cross section. Since a sectional shape of flat-shaped flow passage unit 60 is a shape in which plate members are overlaid, circulation flow passage 60a is formed in a rectangle in cross section, for example, a groove is formed in one plate member and is joined with another plate member, thereby forming circulation flow passage 60a easily. Piezoelectric pump 1 is connected to both ends of circulation flow passage 60a, and thus is formed

in one closed-structure flow passage in association with circulation flow passage 60a. Cooling system 10 effects the operation of piezoelectric pump 1 such that the liquid is circulated in circulation flow passage 60a to dissipate the heat of the liquid that is heated by the parts that have been heated.

[0026]

Hereinafter, piezoelectric pump 1 is explained in detail with reference to Fig. 2. Fig. 2 shows the piezoelectric pump of the first embodiment, Fig. 2(a) is a lateral section view, and Fig. 2(b) is a longitudinal section view viewed from an upper surface side.

[0027]

Piezoelectric pump 1 is provided with pressure chamber 50 in which a part is formed by piezoelectric oscillator 30, and suction port 21a and discharge port 21b are each connected to pressure chamber 50. Suction valve 20a and discharge valve 20b are respectively arranged in the vicinity of suction port 21a and discharge port 21b. When piezoelectric oscillator 30 oscillates, the pressure in pressure chamber 50 is changed, and the liquid flows from suction port 21a to discharge port 21b in the direction indicated by the arrows in Fig. 2.

[0028]

Pressure chamber 50 is arranged between lower plate 11 and upper plate 12 which provide a cabinet for piezoelectric pump 1. Pressure chamber 50 is formed in a flat shape with a rectangular lower surface. At one end of pressure chamber 50, suction port 21a into which the liquid flows, is formed, and at the other end, discharge port 21b from which the liquid flows, is formed. Both suction port 21a and discharge port 21b are positioned on the center line in the longitudinal direction of pressure chamber

50 formed in the rectangle viewed from the upper surface.

[0029]

Suction side flow passage 70a connected with circulation flow passage 60a shown in Fig. 1 is formed so that it is connected with suction port 21a, and discharge side flow passage 70b similarly connected with circulation flow passage 60a is formed so that it is connected with discharge port 21b. Suction side flow passage 70a and discharge side flow passage 70b are arranged in a line on the center line and are extended in the same direction while pressure chamber 50 is positioned between these flow passages. Suction side flow passage 70a and discharge side flow passage 70b are formed having similar shapes, and sections thereof are rectangles. Flow passage 70a and flow passage 70b are formed in rectangles in the cross section, and thus they can be formed easily by the cutting process or the extruding process.

[0030]

A height of pressure chamber 50 is approximately similar to that of suction side flow passage 70a. Also, the flow passage in piezoelectric pump 1 is formed into a flat shape by positioning the lower surface of pressure chamber 50 and the lower surfaces of suction side flow passage 70a and discharge side flow passage 70b on the same plan.

[0031]

Piezoelectric oscillator 30 is prepared as a diaphragm in which an oscillating plate (not shown) is put between two piezoelectric elements (not shown) which are bonded together, and is arranged so as to operate on the upper surface of flat-shaped pressure chamber 50. Also, an electrode (not shown) for applying a voltage to the piezoelectric elements is formed. By

applying an alternating voltage to piezoelectric oscillator 30 structured in this way, piezoelectric oscillator 30 bends and oscillate in the thickness direction of the plate.

[0032]

Lead zirconate titanate ceramic materials may be used, for example, as piezoelectric elements. The oscillating plate and the piezoelectric elements are bonded together by various techniques in accordance with the materials of the oscillating plate. For example, when ceramic or silicon is used as the oscillating plate, the piezoelectric elements can be integrated with the oscillating plate by a print firing method, a sputtering method, a sol-gel method, or a chemical vapor method. Incidentally, in the first embodiment, the piezoelectric elements are used as a driving source to oscillate the diaphragm, however, the driving source is not limited to piezoelectric elements and may be anything capable of oscillating the diaphragm.

[0033]

In suction side flow passage 70a and discharge side flow passage 70b, suction valve 20a and discharge valve 20b made of thin metal plates, such as aluminum, are respectively provided. Valves 20a, 20b are arranged so as to diagonally intersect the flow direction of liquid. As to both valves 20a, 20b, upstream ends in the flow direction are supported by cantilevers and downstream ends are free ends abutting on side walls of flow passages 70a, 70b without water load. Accordingly, suction valve 20a opens suction side flow passage 70a when negative pressure is generated in pressure chamber 50, and closes flow passage 70a when positive pressure is generated in pressure chamber 50. On the other hand, discharge valve 20b

closes flow passage 70b when negative pressure is generated in pressure chamber 50, and closes flow passage 70b when positive pressure is generated.

[0034]

Additionally, sectional shapes of suction side flow passage 70a and discharge side flow passage 70b may be circles or so-called D-shapes in which a part of a circle is cut by a straight line. However, flow passages 70a, 70b are formed in a rectangle in the cross section as in the first embodiment, thereby forming valves 20a, 20b in simple shapes. Further, valves 20a, 20b can be attached by a relatively easy method, for example, by bonding one end of a valve member to one wall face in a flow passage.

[0035]

Next, explanations are given of the operation of piezoelectric pump 1 structured as described above.

[0036]

First, a voltage of a predetermined polarity is applied to piezoelectric oscillator 30, and piezoelectric oscillator 30 is displaced so as to have an upward convex orientation in Fig. 2. Then, the volume of pressure chamber 50 is increased, and the pressure in pressure chamber 50 becomes negative pressure. With this operation, suction valve 20a is displaced and suction port 21a is opened, and the liquid flows into pressure chamber 50 via suction side flow passage 70a and suction port 21a. At this time, discharge valve 20b blocks discharge port 20b, and no liquid flows from discharge port 21b.

[0037]

Successively, a voltage of an inverse polarity to the above polarity is applied to piezoelectric oscillator 30, and piezoelectric oscillator 30 is

displaced so as to have a downward convex orientation in Fig. 2. With this operation, the volume in pressure chamber 50 is reduced. Then, discharge valve 20b is displaced and discharge port 21b is opened, and the liquid is discharged from pressure chamber 50 via discharge side flow passage 70b. At this time, suction valve 20a blocks suction side flow passage 70a, and no liquid flows and is discharged into/from suction port 21a.

[0038]

By repeating the above-mentioned operations, suction of liquid from suction port 21a and discharge of the liquid from discharge port 21b are alternately repeated, and the liquid pulsates. Accordingly, the liquid circulates through circulation flow passage 60a in the direction indicated by arrows shown in Fig. 1(a) by the operation of piezoelectric pump 1.

[0039]

In the first embodiment, the flow passage in piezoelectric pump 1 is formed into a flat shape without being bent in the thickness direction of the piezoelectric pump. Specifically, all of suction side flow passage 70a, pressure chamber 50, and discharge side flow passage 70b are formed on lower plate 11. Suction side flow passage 70a and discharge side flow passage 70b are positioned on a straight line and are extended in the same direction so that presser chamber 50 is positioned between the passages. As a result, the flow passage of piezoelectric pump 1 is formed in a flat shape and in a straight line. Therefore, compared with the conventional piezoelectric pump in which the flow passage is bent, piezoelectric pump 1 can reduce the pressure loss caused by a change of the flow direction of the liquid and can circulate the liquid efficiently. Further, in piezoelectric pump 1, suction valve 20a and discharge valve 20b are installed to tilt relative to the

flow direction of the liquid. Accordingly, compared with a valve arranged orthogonally to the flow direction, suction valve 20a and discharge valve 20b are displaced with a small force, and the pressure loss of the liquid can be further reduced. As described above, piezoelectric pump 1 is improved in pump efficiency compared with the conventional one, and cooling system 10 (refer to Fig. 1) is also improved in cooling efficiency with the improvement in pump efficiency. Incidentally, in the first embodiment, both suction valve 20a and discharge valve 20b are tilted relative to the flow direction, however, it is possible to tilt only one discharge valve.

[0040]

Also, in the first embodiment, since flow passages 70a, 70b are positioned at both ends of pressure chamber 50, the flow passage is formed into a flat shape and the whole of piezoelectric pump 1 is reduced in thickness. Further, since piezoelectric oscillator 30 is arranged so as to operate on one surface that has the large area of pressure chamber 50 formed in a flat rectangular parallelepiped shape, the bending displacement of piezoelectric oscillator 30 can be transmitted to pressure chamber 50 efficiently. Accordingly, relatively small piezoelectric oscillator 30 can obtain a sufficient amount of flow, and piezoelectric pump 1 can be reduced in size as a result. Additionally, in the first embodiment, one piezoelectric oscillator 30 is arranged on the upper surface of pressure chamber 50, however, the number of piezoelectric oscillators and their shape thereof are not limited. For example, two piezoelectric oscillators are arranged for upper and lower surfaces of pressure chamber 50.

[0041]

As described above, cooling system 1 using piezoelectric pump 1 that

enables a reduction in thickness and an increase in pump efficiency can circulate the liquid efficiently. Further, for example, by arranging parts that have been heated directly to or in the vicinity of flow passage unit 60, heat from the parts can be dissipated efficiently.

[0042] (Second Embodiment)

In the first embodiment, the pressure chamber is formed in a rectangular parallelepiped shape, however, the pressure chamber may be formed so that the cross-sectional area of the pressure chamber is gradually varied in order to reduce the resistance of the liquid.

[0043]

Fig. 3 shows the piezoelectric pump of the second embodiment according to the present invention. Piezoelectric pump 2 shown in Fig. 3 is formed so that pressure chamber 50' is formed in a streamlined shape. On peripheral walls of pressure chamber 50', structural parts (retuning grooves 11a) for accelerating the flow of the liquid are arranged. The other structures are similar those of piezoelectric pump 1 shown in Fig. 2, and the same numeral references are applied to the structural parts having the same functions and explanations thereof are omitted.

[0044]

Pressure chamber 50', as shown in Fig. 3(b), is provided with peripheral wall surface 11e in an approximate streamlined shape viewed from the upper surface. Peripheral wall surface 11e is arranged vertically to bottom part 11b of pressure chamber 50'. Also, peripheral wall surfaces 11e are respectively connected with suction port 21a and discharge port 21b, and are bent in an arc shape toward the outside. Incidentally, the arc shape is preferably set, as appropriate, in accordance with the kind of liquid or

characteristics of piezoelectric oscillator 30 so that the resistance of the liquid is reduced as far as possible.

[0045]

A plurality of retuning grooves 11a is formed on the peripheral wall of pressure chamber 50' so as to open peripheral wall surface 11e. In the second embodiment, five retuning grooves 11a are arranged at predetermined intervals to have the same groove width. Also, respective retuning grooves 11a are extended from a point (not shown) as the center in the vicinity of discharge port 21b in the radiation direction. In other words, opening parts of returning grooves 11a are directed to the point in the vicinity of discharge port 21b. Preferably, the point is positioned at the center of discharge port 21b.

[0046]

A detailed shape of returning groove 11a is explained with reference to Fig. 4. Fig. 4 is a perspective enlarged view showing one returning groove 11a and the flow direction of liquid around groove 11a. As shown in Fig. 4, returning groove 11a is opened to upper edge surface 11c, the upper surface of the peripheral wall, and to peripheral wall surface 11e. Also, returning groove 11a gradually becomes deeper toward one end (side of peripheral wall surface 11e).

[0047]

On the peripheral side of upper edge surface 11c, convex part 11d having a predetermined height relative to upper edge surface 11c is formed. In the second embodiment, piezoelectric oscillator 30 (refer to Fig. 3(a)) is positioned on the upper surface of convex part 11a. Accordingly, a predetermined space is formed between upper edge surface 11c and

piezoelectric oscillator 30, and the space is a part of pressure chamber 50'. With this arrangement, when piezoelectric oscillator 30 is displaced so as to have a downward convex orientation, the liquid flows into the opening part at the upper surface side of returning groove 11a, passes through retuning groove 11a, and is discharged from the opening part of peripheral wall surface 11e.

[0048]

In piezoelectric pump 2 arranged as described above, peripheral wall surface 11e in pressure chamber 50' is formed in a streamlined shape, and the cross-sectional area thereof continuously becomes smaller toward suction side flow passage 70a and discharge side flow passage 70b. Accordingly, the resistance between the liquid and peripheral wall surface 11e is reduced, and the pressure loss in pressure chamber 50' is further reduced. Also, when piezoelectric oscillator 30 is displaced and the liquid is discharged from discharge side flow passage 70b (refer to Fig. 3), the liquid in the retuning groove 11a is discharged toward discharge port 21b. Therefore, the flow of the liquid in pressure chamber 50' is accelerated, and piezoelectric pump 2 is further improved in pump efficiency. In particular, since each retuning groove 11a is opened toward discharge port 21b, the liquid discharged from retuning groove 11a accelerates the flow of the liquid more efficiently.

[0049]

Incidentally, the number of retuning grooves 11a and the shape thereof, and the height of convex part 11d are preferably set, as appropriate, in accordance with the kind of liquid or the shape of discharge port 20b. For example, in accordance with the shape of the pressure chamber and the

position of the discharge port, only one retuning groove 11a may be formed. However, like the second embodiment, in the case of pressure chamber 50' formed symmetrically with respect to the axial line of flow passages 70a, 70b, as shown in Fig. 3(b), retuning grooves 11a are preferably formed symmetrically with respect to the axial line. With this arrangement, the liquid flows symmetrically with respect to the axial line.

[0050]

As to the shape of retuning groove 11a, as shown in Fig. 5, the width of retuning groove 11a' may be tapered toward pressure chamber 50', and the liquid in returning groove 11a' may be discharged from the tip of returning groove 11a' at high speed. With this arrangement, the flow of the liquid is further accelerated, and pump efficiency is further improved.

[0051]

Also, in piezoelectric pump 2 shown in Fig. 3, while the height of pressure chamber 50' is constant, peripheral wall surface 11e is bent so that the length orthogonal to the axial line of flow passages 70a, 70b continuously becomes shorter toward flow passages 70a, 70b, and the cross-sectional area of pressure chamber 50' becomes smaller toward suction port 21a and discharge port 21b. However, the shape of the pressure chamber is not limited to this description as long as the cross-sectional area becomes smaller continuously.

[0052]

For example, as shown in Fig. 6, taper 12a may be arranged at the corner part of pressure chamber 50". In other words, the height of pressure chamber 50" is continuously lowered toward suction port 21a or discharge port 21b so that the cross-sectional area thereof becomes smaller. With this

arrangement, the resistance of the liquid passing through pressure chamber 50" is reduced, and the pressure loss of the liquid is reduced.

[0053] (Third Embodiment)

Generally, a closed-structure flow passage in cooling system 10 shown in Fig. 1 is filled up with the liquid so that no bubbles remain. However, for example, there is a case in which dissolved oxygen is changed into bubbles and the bubbles are mixed into the liquid. In a piezoelectric pump, the existence of bubbles inside the flow passage causes a reduction in pump efficiency. Further, the existence of bubbles inside the closed-structure flow passage causes a reduction in cooling efficiency of cooling system 10.

[0054]

So, in order to further improve pump efficiency, in addition to the two above-mentioned embodiments, a piezoelectric pump may be provided with means for collecting bubbles mixed in the liquid.

[0055]

Respective piezoelectric pumps 3, 3', 3" shown in Fig. 7 to Fig.9 are provided with gaseous chambers 35, 35', 35". Figs. 7(a), 8(a) and 9(a) are lateral section views of piezoelectric pumps 3, 3', 3", and Figs. 7(b), 8(b) and 9(b) are longitudinal section views of gaseous chambers 35, 35', 35".

[0056]

Piezoelectric pump 3 shown in Fig. 7 has gaseous chamber 35 over piezoelectric oscillator 30. The other structures are similar to those of piezoelectric pump 1 shown in Fig. 2, and the same numeral references are applied to the structural parts having the same functions as Fig. 2 and explanations thereof are omitted.

[0057]

Gaseous chamber 35 is formed by piezoelectric oscillator 30 and by the cabinet of piezoelectric pump 3, and covers suction side flow passage 70a and discharge side flow passage 70b.

[0058]

At the somewhat upstream side to suction valve 20a, one intake 35a for introducing bubbles into gaseous chamber 35 is arranged. Intake 35 is a hole for connecting suction side flow passage 70a and gaseous chamber 35 and is positioned on the upper surface of suction side flow passage 70a.

[0059]

When piezoelectric pump 3 is applied to cooling system shown in Fig. 1, a closed-structure flow passage is formed by the flow passage in cooling system 10 and gaseous chamber 35. Then, the flow passage is completely filled up with the liquid to be circulated. In other words, in the initial state of cooling system 10, atmospheric pressure chamber 35 is also filled up with the liquid.

[0060]

In cooling system 10 structured like this, when bubbles are generated in the liquid, the bubbles move through circulation flow passage 60 (refer to Fig. 1) by the flow of the liquid. Then, the bubbles which have moved along the upper wall of suction side flow passage 70a are taken into intake 35a and float upward. At the same time, the liquid in gaseous chamber 35 is pushed out from intake 35a by the bubbles, and the bubbles are collected in gaseous chamber 35. With this operation, in piezoelectric pump 3, the bubbles can be removed from the flow passage in cooling system 10, and the liquid can be circulated without a reduction in pump efficiency.

[0061]

Incidentally, in the third embodiment, as shown in Fig. 7(b), the shape of the opening of intake 35a is formed in a circle. There are no particular limitations to the shape of intake 35a, as long as bubbles can be collected, for example, an oblong hole (not shown) extending in the width direction of suction side flow passage 70a may be formed. With this arrangement, bubbles moving along the upper wall of flow passage 70a can be collected efficiently. Further, when two intakes are provided, bubbles enter gaseous chamber 35 through one of the intakes while liquid is discharged from the other intake. In this way, the operation of changing bubbles and liquid may be performed smoothly. Needless to say, in order to collect bubbles efficiently, intake 35 may be arranged so as to be higher relative to flow passage 70a, and grooves and cut parts for guiding the bubbles to intake 35 may be formed.

[0062]

Additionally, piezoelectric pump according to the third embodiment may be variously changed as shown Figs. 8 and 9. In piezoelectric pump 3' in Fig. 8, piezoelectric oscillator 30 is arranged on the lower surface of pressure chamber 50. In piezoelectric pump 3" in Fig. 9, gaseous chamber 35" is arranged in a loop area. Both of piezoelectric pumps 3', 3" are not different from piezoelectric pumps 3 substantially, and gaseous chambers 35, 35', 35" function similarly.

[0063]

As described above, according to the third embodiment, piezoelectric pump 3 is provided with gaseous chamber 35, and bubbles generated in liquid can be collected. Therefore, piezoelectric pump 3 is improved in pump

efficiency. Also, high cooling efficiency in cooing system 10 is maintained for a long period. Further, in the cooling system 10 having piezoelectric pumps 3, 3', 3" explained in the third embodiment, when liquid is expanded by a change of environmental temperature or the like, the volume change is absorbed by gaseous chambers 35, 35', 35". Therefore, piezoelectric pumps 3, 3', 3" and the flow passage in cooling system are prevented from being broken.

[0064]

Representative embodiments have been explained, however, elements explained in each embodiment may be combined freely as far as possible.